Poultry Science®

The amino acid pattern and dynamics of body protein, body fat deposition in male and female broilers under different temperatures

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ABSTRACT The present study was conducted 1) to investigate the effects of gender and temperature on growth performance in broiler chickens and 2) to establish body protein and fat deposition curves and amino acid patterns for broilers of both genders at different ambient temperatures. A total of 432 1-day-old (**d**) Arbor Acres chickens with a male/female ratio of 1:1 were randomly divided into the following 4 treatment groups: the male thermoneutral group, the female thermoneutral group, the male heat stress group, and the female heat stress group. The chickens in the thermoneutral groups were kept at a comfortable temperature from 1 to 42 d, while chickens in the heat stress groups were kept at a comfortable temperature from 1 to 28 d and at a high ambient temperature from d 29 to 42. The body composition retention data were obtained by comparative slaughter method, and the models were constructed by the Gompertz model. The results revealed significant variation in body protein content (**BPC**) and body fat deposition efficiency (**BFE**) between both genders and the 2 temperatures. Moreover, a noteworthy interaction between gender and temperature was observed in terms of the BPC and protein deposition efficiency (**BPE**). The following equations for body protein and body fat deposition in the thermoneutral groups were obtained:

Body protein weight of male broilers: $\mathrm{BPW(t)} = 1843.6\mathrm{e}^{-5.1366\mathrm{e}^{-0.0388\mathrm{t}}}$;
Body protein weight of female broilers: $\mathrm{BPW(t)} = 1293.8\mathrm{e}^{-4.7438\mathrm{e}^{-0.0417\mathrm{t}}}$;
Body fat weight of male broilers: $\mathrm{BFW(t)} = 1702.7\mathrm{e}^{-6.1452\mathrm{e}^{-0.0336\mathrm{t}}}$;
Body fat weight of female broilers: $\mathrm{BFW(t)} = 1031.4\mathrm{e}^{-5.9759\mathrm{e}^{-0.0416\mathrm{t}}}$.

Where t means age (d).

The following equations for body protein and body fat deposition in the heat stress groups were obtained:

Body protein weight of male broilers: $\mathrm{BPW(t)} = 992.1\mathrm{e}^{-4.9603\mathrm{e}^{-0.0527\mathrm{t}}}$;
Body protein weight of female broilers: $\mathrm{BPW(t)} = 881.2\mathrm{e}^{-4.7077\mathrm{e}^{-0.0517\mathrm{t}}}$;
Body fat weight of male broilers: $\mathrm{BFW(t)} = 1183.2\mathrm{e}^{-6.2350\mathrm{e}^{-0.0403\mathrm{t}}}$;
Body fat weight of female broilers: $\mathrm{BFW(t)} = 700.3\mathrm{e}^{-6.1667\mathrm{e}^{-0.0514\mathrm{t}}}$.

Where t means age (d).

In addition, no significant difference in amino acid content was found between different genders and temperatures. The amino acid pattern could be divided into 2 stages: 0 to 14 d and 15 to 42 d. Our equations and patterns enable a deeper understanding of the nutritional requirements in broiler chickens under various temperature conditions. This enables researchers to develop more accurate feeding programs to fulfill the growth and health requirements of broiler chickens.

Key words: body protein, body fat, amino acid, broiler, temperature

2024 Poultry Science 103:103525
https://doi.org/10.1016/j.psj.2024.103525

INTRODUCTION

The poultry industry is becoming increasingly significant in global agriculture (Mottet and Tempio, 2017). As a key component of the poultry industry, the broiler sector has witnessed a continuous increase in production volume over the years. During the last decades, the growth rate and the lean muscle yield of broilers have increased (Havenstein et al., 2003), and broilers reach a mature body weight at an earlier age (Gous, 1986; Tallentire et al., 2016; Tavárez and Solis de los Santos, 2016; Livingston et al., 2020). For example, the time to reach the slaughter weight of 2.3 kg has been reduced from 52 d in 1995 to 36 d in 2017, and the breast meat yield has

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Received November 14, 2023.
Accepted January 27, 2024.

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increased from 12% of body weight in 1957 to 24% in 2023 (Aftab, 2019; Wu et al., 2024) . The rapid growth and high lean meat yield are direct outcomes of genetic selection (Havenstein et al., 2003). Due to these advancements, the protein, fat, and amino acid compositions of the present strains might be quite different from those in the past.

Modern broiler strains are characterized by higher nutrient requirements than previously used strains (Dozier et al., 2008). Moreover, there is considerable variation in the daily nutritional requirements of fast-growing broiler chickens (Caldas et al., 2019). Futhermore, many reports indicated variation in body composition between genders (Zuidhof et al., 2014; Livingston et al., 2020). Based on these findings, it is crucial for the poultry industry to explore the growth patterns of modern fast-growing broiler chickens in order to develop more accurate and effective broiler nutrition standards.

Generally, the optimal growth potential of the researcher's nutritional standards is based on the proper external factors, hardly investigated under abnormal environmental conditions. However, the intensive selection for faster growth has increased the sensitivity to high ambient temperatures in broilers (Cahaner and Leenstra, 1992; Cahaner et al., 1995; Lu et al., 2007). Heat stress has a negative impact on poultry productivity, especially in tropical areas (Lara and Rostagno, 2013), affecting body composition (Shakeri et al., 2019; Zhang et al., 2020; Al-Abdullatif and Azzam, 2023), ultimately reducing the quality of broiler meat products (Syafwan et al., 2012; Malila et al., 2022). Therefore, it is essential to develop a nutritional requirement program specifically tailored for broilers in high-temperature environments.

Predicting the growth of broilers and determining the age of maximum growth rate and optimal sale time are crucial elements that affect the profitability of poultry enterprises. An increasing number of studies are utilizing growth models to determine the relationship between body composition and age in broilers (Kuhi et al., 2010).

However, in the existing research, gender, and temperature effects are rarely simultaneously considered. The objective of the present study was 1) to establish the growth curves in terms of body protein and body fat deposition and 2) to explore the amino acid patterns of broilers of both genders under different ambient temperatures. In doing so, we can establish the optimal market age, meeting the demands of the poultry companies and reducing production costs. The results can serve as the basis for the subsequent establishment of prediction models for broiler nutrition and energy requirements.

MATERIALS AND METHODS

The study was approved by the Institutional Ethics Committee of Experiment Animal Welfare and Ethics at the Institute of Animal Science of the Chinese Academy of Agricultural Sciences (**CAAS**) (permit number: IAS2022-154).

Birds and Housing

A total of 500 1-day-old (**d**) Arbor Acres chickens with equal proportion between male and female purchased from a commercial hatchery (Luanping Yijia Agricultural Development Co., Ltd., Hebei, China), 432 birds with similar weight were selected and reared in a single-layer flat cage (0.82 m × 0.07 m × 0.06 m). Birds were randomly divided into 4 treatment groups including the male thermoneutral group, the female thermoneutral group, the male heat stress group, and the female heat stress group. There were 6 replicates with 18 birds per replicate in each treatment group.

The experimental period lasted for 42 d (1−42 d). Heat stress hardly occurs during 0 to 4 weeks-old broilers in view of those chickens equipped with lower heat production and a promoted well-controlled climate environment in China. Thus, the environmental temperature and humidity were set according to the Arbor Acres Broiler Management Handbook (Aviagen, 2018) for all 4 treatment groups during the first 4 wk. The ambient temperatures of the thermoneutral groups were maintained at 23° C ± 2°C, and the heat stress groups were maintained at 33°C ± 2°C during 29 to 42 d. The relative humidity of the 4 treatment groups was maintained at 60%.

The experiment was conducted in 4 artificial climate chambers (4.08 m × 2.88 m × 2.38 m) belonging to the Institute of Animal Sciences of CAAS. During the experiment, climate chamber parameters were configured to simulate authentic productional environments. Other settings were kept identical for all chambers.

Diets and Feeding Program

All birds were fed a corn-soybean ad libitum diet from 1 to 42 d, the diet is formulated in 4 feeding programs (1−7 d, 8−21 d, 22−33 d, and 35−42 d) according to Brazilian Tables for Poultry and Swine (Rostagno et al., 2011) (Table 1). Dietary crude protein content determination was conducted by using a Kjeldahl nitrogen analyzer, and dietary crude fat content determination was conducted by using a Soxhlet extractor, while the dietary metabolizable energy determination was performed in the State Key Laboratory of Animal Nutrition and Feeding according to the bionic digestive Operation manual SDS3.

Body Composition Measurements

The sampling day is as follows: 1, 7, 14, 21, 28, 35, 42 d. During the sampling period, the average daily feed intake and the average body weight (**BW**) for each replicate were recorded at 8 am after 12 h of feed deprivation for emptying the gastrointestinal tract. Then 2 birds, close to average weight, were selected from each replicate euthanized by CO_2 inhalation humanely. Thereafter, immerse them into a bucket filled with 70°C to 80°C water, about 3 min after, isolate the carcass and the feathers with a feather removal machine, after drying the de-feathered carcasses, the carcasses weight (**CW**) was recorded, and the feather weight (**FW**) (Syafwan et al.

Table 1. Composition and nutrient levels of the basal diet.

	Content			
Items	1−7 d	8−21 d	22−33 d	34−42 d
Ingredients (%)				
Corn	51.44	54.08	56.85	60.98
Soybean meal	40.21	36.82	33.86	30. 12
Soybean oil	3.94	5.00	5.50	5.50
Limestone	1.00	0.85	0.90	0.70
$CaHPO_4$	1.89	1.80	1.50	1.30
NaCl	0.30	0.30	0.30	0.30
DL-Methionine	0.21	0. 19	0. 19	0. 18
L-Lysine	0.36	0.32	0.30	0.30
L-Threonine	0. 15	0. 14	0. 10	0. 12
premix[1]	0.50	0.50	0.50	0.50
Total	100	100	100	100
Nutrient levels[2]				
ME, Kcal/Kg	2961	3038	3095	3199
CP (%)	22. 55	21.18	19.97	18.66
EE(%)	10.54	10.38	11.35	12.03
Ca (%)	0.94	0.85	0.79	0.66
AP (%)	0.43	0.41	0.35	0.31
L-Lysine (%)	1.46	1.34	1.25	1. 17
L-Methionine (%)	0.54	0.51	0.49	0.47
DL-Methionine + L-Cysteine (%)	0.92	0.87	0.84	0.80

[1] Premix provided the following per kg of the diet: 1−7 d: vitamin A 12,000 IU, vitamin D3 5,000 IU, vitamin E 80 mg, vitamin K3 3.2 mg, vitamin B1 3.2 mg, vitamin B2 8.6 mg, vitamin B6 4.3 mg, vitamin B12 17 μg, pantothenic acid calcium 20 mg, nicotinic acid 65 mg, folic acid 2.2 mg, biotin 0.22 mg, choline 1,020 mg, Cu ($CuSO_4 \cdot 5H_2O$) 16 mg, Fe ($FeSO_4 \cdot 7H_2O$) 20 mg, Zn ($ZnSO_4 \cdot 7H_2O$) 110 mg, Mn ($MnSO_4 \cdot H_2O$) 120 mg, Se (Na_2SeO_3) 0.3 mg, I (KI) 1.25 mg; 8−21 d: vitamin A 10,000 IU, vitamin D3 4,500 IU, vitamin E 65 mg, vitamin K3 3.0 mg, vitamin B1 2.5 mg, vitamin B2 6.5 mg, vitamin B6 3.2 mg, vitamin B12 17 μg, pantothenic acid calcium 18 mg, nicotinic acid 60 mg, folic acid 1.9 mg, biotin 0.18 mg, choline 1,020 mg, Cu ($CuSO_4 \cdot 5H_2O$) 16 mg, Fe ($FeSO_4 \cdot 7H_2O$) 20 mg, Zn ($ZnSO_4 \cdot 7H_2O$) 110 mg, Mn ($MnSO_4 \cdot H_2O$) 120 mg, Se (Na_2SeO_3) 0.3 mg, I (KI) 1.25 mg; 22−32 d: vitamin A 9,000 IU, vitamin D3 4000 IU, vitamin E 55 mg, vitamin K3 2.2 mg, vitamin B1 2.2 mg, vitamin B2 5.4 mg, vitamin B6 2.2 mg, vitamin B12 11 μg, pantothenic acid calcium 15 mg, nicotinic acid 45 mg, folic acid 1.6 mg, biotin 0.15 mg, choline 950 mg, Cu ($CuSO_4 \cdot 5H_2O$) 16 mg, Fe ($FeSO_4 \cdot 7H_2O$) 20 mg, Zn ($ZnSO_4 \cdot 7H_2O$) 110 mg, Mn ($MnSO_4 \cdot H_2O$) 120 mg, Se (Na_2SeO_3) 0.3 mg, I (KI) 1.25 mg.

[2] Nutrient levels were measured value.Abbreviations: AP, available phosphorus; CP, crude protein; EE, ether extract; ME, metabolizable energy.

2012) can be calculated by subtracting CW from BW. Feather and carcass samples were collected and frozen in a −20°C refrigerator for further analysis.

Carcass Sample Handling. Briefly, carcass samples were thawed at 25°C for 4 h and crushed with a large meat grinder to primary specimens. After homogenization thoroughly, 300 g primary sample were collected and placed in a 105°C oven about 15 min for sterilization, and then placed in a 65°C oven for 72 h for air drying. Thereafter, the carcass dry matter (**DM**) content was weighed. Dried samples were ground with a small grinder for further analysis.

Feather Sample Handling. All the feather samples were placed in tinfoil boxes and dried in an oven at 65°C for 72 h. After drying, record the dried samples weight and keep them at 25°C for 12 h. The moisture return water content were determined as the samples' water content, the feather sample DM content was determined by subtracting water content from 100%. Dried samples were ground with a small grinder for further analysis.

Sample Index Determination. The Kjeldahl nitrogen analyzer was used for DM crude protein content determination follows the Chinese standard (GB/T 6432-1994). The Soxhlet extractor was used for DM crude fat content determination follows the Chinese standard (GB/T 6433-2006). The automatic amino acid analyzer was used for sample amino acid content determination follows the Chinese standard (GB/T 18246-2000), the amino acid content was expressed as the proportion of crude protein.

Calculations and Statistical Analysis

Body Composition Analysis. The body protein content (**BPC**) and body protein proportion (**BPP**) were calculated as follows:

$$\mathrm{BPC} = \mathrm{CPC} + \mathrm{FPC}$$

$$\mathrm{BPP} = \mathrm{BPC}/\mathrm{BW};$$

Where BPC means body protein content (g); CPC means carcass protein content (g); FPC means feather protein content (g); BPP means body protein proportion (%); BW means body weight (g).

The body protein retention rate (**BPR**) was calculated as follows:

$$\mathrm{BPR} = \mathrm{BPG}/\mathrm{BWG}$$

Where BPR means body protein retention rate (g/kg); BPG means body protein gain (g); BWG means body weight gain (kg).

The protein deposition efficiency (**BPE**) was calculated as follows:

$$\mathrm{BPE} = \mathrm{BPG}/(\mathrm{FI} \times \mathrm{FPC})$$

Where BPE means body protein deposition efficiency (%); BPR means body protein gain (g); FI means feed intake (g); FCP means feed crude protein content (%).

The body fat content (**BFC**) and body fat proportion (**BFP**) was calculated as follows:

$$\mathrm{BFC} = \mathrm{CFC} + \mathrm{FFC};$$

$$\mathrm{BFP} = \mathrm{BFC}/\mathrm{BW};$$

Where BFC means body fat content (g); CFC means carcass fat content (g); FFC means feather fat content (g); BFP means body fat proportion (%); BW means body weight (g).

The body fat retention rate (**BFR**) was calculated as follows:

$$\mathrm{BFR} = \mathrm{BFG}/\mathrm{BWG}$$

Where BFR means body fat retention rate (g/Kg); BFG means body fat gain (g); BWG means body weight gain (Kg);

The body fat deposition efficiency (**BFE**) was calculated as follows:

$$\mathrm{BFE} = \mathrm{BFG}/(\mathrm{FI} \times \mathrm{FCF})$$

Where BFE means body fat deposition efficiency (%); BFR means body fat gain (g); FI means feed intake (g); FCF means feed crude fat content (%).

Body Protein and Body Fat Deposition Curves. To investigate the relationship between age and body composition, the Gompertz curves were used to fit the retention data set by the NLIN procedure of SAS software as follows:

$$\mathrm{Y(t)} = \beta 0 \times \mathrm{e}^{(-\beta 1 \times \mathrm{e}^{-(\beta 2 \times \mathrm{t})})},$$

Where t means age (d); $\beta 0$ means asymptote (progressive value of the maximum weight, mature weight), $\beta 1$ means related to the age at the inflection point; $\beta 2$ means related to the maximum growth rate at the inflection point. The accuracy of the curves was measured by calculating the coefficient of determination (R^2). According to the parameters of the models, the age at maximum growth rate (**AIP**, age at the inflection point), body weight at maximum growth rate (**WIP**, body weight at inflection point), and the maximum growth rate (**MWG**) can be determined by equations as follows.

$$\mathrm{AIP} = (\ln\beta 1)/\beta 2$$

$$\mathrm{WIP} = \beta 0/\mathrm{e}$$

$$\mathrm{MWG} = \beta 2 \times \mathrm{WIP}.$$

The graphs of Gompertz growth models were generated with GraphPad Prism 8 (GraphPad Software, Inc., San Diego, CA).

Amino Acid Composition and Pattern. The amino acid composition in broiler chickens is quantified as the ratio of each amino acid content to the body crude protein content. Thereafter, determining the amino acid pattern with lysine serving as the standard reference.

Statistical Analysis. Mean ± standard error values are provided in the Tables 2−9, 11−13. Gender differences in broiler growth performance and body composition were analyzed as repeated measures using the SPSS Statistics 26 (IBMCorp., Armonk, NY) one-way analysis of variance (**ANOVA**). A 2-way ANOVA was performed using SPSS Statistics 26 to examine the interaction effects of temperature and gender on the measured variables of body weight and body composition. Means were separated using a Duncan test when ANOVA was significant, and the *P*-value was considered significant when $P < 0.05$.

RESULTS

Growth Performance

The gender differences in broiler growth performance are shown in Table 2 and Table 3. From 14 d onwards, for BW, that males were significantly higher than that of females. For CW, males exhibiting higher weight at 14 d, 28 d, 35 d, 42 d in all groups. Except for at 21 d, there are no significant differences in FW were observed between males and females. At 21 d, the females exhibited a higher FW compared to the males. Furthermore, the data presented in Table 4 indicated that there was no interaction effect of genders and temperatures on the BW, CW, and FW.

Body Protein and Body Fat Composition

Tables 5−8 presents the gender difference in body composition retention. Table 5 and Table 7 demonstrate

Table 2. Gender difference in growth performance of broilers in thermoneutral groups.

Items[1]	Sex[2]	Age, d						
		1	7	14	21	28	35	42
BW, g	M	43.68 ± 0.04	180.89 ± 1.35	553.29 ± 5.48^{a}	1052.66 ± 5.27^{a}	1844.89 ± 24.67^{a}	2474.87 ± 41.18^{a}	3213.90 ± 42.18^{a}
	F	43.56 ± 0.05	176.76 ± 2.96	519.39 ± 6.98^{b}	939.49 ± 16.78^{b}	1681.81 ± 57.31^{b}	2192.02 ± 38.66^{b}	2822.10 ± 51.62^{b}
	P-value	0.07	0.23	<0.01	<0.01	0.03	<0.01	<0.01
CW, g	M	47.4 ± 1.13	153.47 ± 6.18	479.55 ± 4.63^{a}	936.63 ± 22.78	1513.02 ± 35.19^{a}	2189.28 ± 51.93^{a}	3127.29 ± 50.24^{a}
	F	45.28 ± 0.68	153.65 ± 4.61	445.95 ± 5.15^{b}	896.83 ± 7.92	1376.53 ± 20.27^{b}	2013.73 ± 22.9^{b}	2760.83 ± 40.00^{b}
	P-value	0.14	0.98	<0.01	0.13	<0.01	<0.01	<0.01
FW, g	M	1.38 ± 0.10	2.42 ± 0.22	8.53 ± 2.07	24.62 ± 1.13^{b}	39.79 ± 3.29	59.04 ± 3.83	82.83 ± 2.85
	F	1.48 ± 0.13	3.07 ± 0.25	13.2 ± 1.17	28.33 ± 0.60^{a}	41.11 ± 2.42	61.71 ± 1.57	77.53 ± 4.03
	P-value	0.55	0.08	0.08	0.04	0.75	0.53	0.31

[a-b] Means within a row with different superscripts significantly different ($P < 0.05$).

[1] BW: body weight; CW: carcass weight; FW: feather weight.

[2] M = male group (n = 6 sampled birds), F = female group (n = 6 sampled birds).

Table 3. Gender difference in growth performance of broilers in heat stress groups (1−28 d with thermoneutral temperature, 29−42 d with high temperature).

Items[1]	Sex[2]	Age, d						
		1	7	14	21	28	35	42
BW, g	M	44.10 ± 0.03	182.16 ± 3.87	543.13 ± 4.80^{a}	1000.66 ± 5.59^{a}	1843.32 ± 24.70^{a}	2323.72 ± 50.64^{a}	2818.67 ± 74.95^{a}
	F	43.91 ± 0.06	176.55 ± 1.22	513.57 ± 2.72^{b}	942.82 ± 7.59^{b}	1665.24 ± 10.74^{b}	2087.00 ± 16.99^{b}	2496.91 ± 33.74^{b}
	P-value	0.06	0.20	<0.01	<0.01	<0.01	<0.01	<0.01
CW, g	M	46.1 ± 1.52	167.95 ± 5.07	470.98 ± 5.38^{a}	898.60 ± 12.21	1466.79 ± 22.22^{a}	2107.98 ± 39.37^{a}	2849.60 ± 57.35^{a}
	F	47.13 ± 1.26	161.15 ± 3.08	437.60 ± 5.32^{b}	867.63 ± 13.25	1358.7 ± 13.97^{b}	1918.64 ± 10.68^{b}	2445.05 ± 56.38^{b}
	P-value	0.61	0.28	<0.01	0.12	<0.01	<0.01	<0.01
FW, g	M	1.17 ± 0.06	1.69 ± 0.15	10.08 ± 0.91	23.39 ± 1.15^{b}	36.80 ± 3.48	59.97 ± 1.87	68.76 ± 3.66
	F	1.33 ± 0.15	2.83 ± 0.42	11.70 ± 0.82	29.42 ± 1.96^{a}	44.73 ± 2.43	63.69 ± 4.95	75.33 ± 2.45
	P-value	0.33	0.07	0.22	0.04	0.09	0.50	0.17

[a-b] Means within a row with different superscripts significantly different ($P < 0.05$).
[1] BW: body weight; CW: carcass weight; FW: feather weight.
[2] M = male group (n = 6 sampled birds), F = female group (n = 6 sampled birds).

Table 4. Interaction effect of gender and temperature on the growth performance of 35 d and 42 d broilers.

Items[1]	Age, d	Treatment[2]				*P*-value[3]		
		TM	TF	HM	HF	Gender	Temperature	Interaction
BW, g	35	2474.87 ± 41.18	2192.02 ± 38.66	2323.72 ± 50.64	2087.00 ± 16.99	<0.01	<0.01	0.56
	42	3213.90 ± 42.18	2822.10 ± 51.62	2818.67 ± 74.95	2496.91 ± 33.74	<0.01	<0.01	0.52
CW, g	35	2189.28 ± 51.93	2013.73 ± 22.9	2107.98 ± 39.37	1918.64 ± 10.68	<0.01	0.02	0.85
	42	3127.29 ± 50.24	2760.83 ± 40	2849.6 ± 57.35	2445.05 ± 56.38	<0.01	<0.01	0.72
FW, g	35	59.04 ± 3.83	61.71 ± 1.57	59.97 ± 1.87	63.69 ± 4.95	0.35	0.67	0.88
	42	82.83 ± 2.85	77.53 ± 4.03	68.76 ± 3.66	75.33 ± 2.45	0.85	0.02	0.09

[1] BW: body weight; CW: carcass weight; FW: feather weight.
[2] TM: thermoneutral male group (n = 6 sampled birds); TF: thermoneutral female group (n = 6 sampled birds); HM: heat stress male group (thermoneutral in 1−28 d, heat stress in 29−42 d) (n = 6 sampled birds); HF: heat stress female group (thermoneutral in 1−28 d, heat stress in 29−42 d) (n = 6 sampled birds).
[3] $P < 0.05$ meant that there was a significant difference between different groups.

a gradual increase in body protein and body fat retention with age. It can be observed that the BPR in males was consistently higher than that in females at 28 to 42 d. Besides, females show higher BPC at 14 d, whereas males exhibit higher BPC during 35 to 42 d. However, the BPC of males was higher than that of females under heat stress only at 42 d.

With respect to the BFC and BFP in each sampling time, that of males was higher than that in females under both 2 conditions at 1 d, and there was a significant difference between genders under heat stress at 42 d. The results show that the BFP of males is higher than females at 1 d, whereas starting from 21 d, females exhibited significantly greater BFC than males.

In addition, Table 6 and Table 8 show the BPE and BFE profile under different conditions. During the stages of 1 to 7 d, 8 to 14 d, and 15 to 21 d, males demonstrated a significantly elevated level of the BPR in comparison to females. Males' BPE shows a significantly higher value during stages 22 to 28 d, 29 to 35 d, and 35

Table 5. Gender difference in body composition of broilers in thermoneutral groups.

Items[1]	Sex[2]	Age, d						
		1	7	14	21	28	35	42
BPC, g	M	9.71 ± 0.28	29.96 ± 1.05	94.84 ± 2.29	196.27 ± 4.14	327.74 ± 7.48^{a}	485.40 ± 11.7^{a}	678.06 ± 10.51^{a}
	F	9.36 ± 0.16	30.49 ± 0.87	93.42 ± 1.27	188.60 ± 1.61	295.22 ± 3.85^{b}	422.72 ± 3.29^{b}	573.02 ± 9.12^{b}
	P-value	0.30	0.71	0.60	0.12	<0.01	<0.01	<0.01
BPP, %	M	19.89 ± 0.11	19.24 ± 0.12	19.42 ± 0.27^{b}	20.43 ± 0.10	21.11 ± 0.15	21.59 ± 0.11^{a}	21.13 ± 0.06^{a}
	F	20.01 ± 0.20	19.46 ± 0.12	20.35 ± 0.17^{a}	20.39 ± 0.04	20.83 ± 0.13	20.37 ± 0.07^{b}	20.19 ± 0.09^{b}
	P-value	0.62	0.21	0.02	0.72	0.18	<0.01	<0.01
BFC, g	M	3.26 ± 0.08^{a}	8.16 ± 0.33	27.83 ± 0.89	91.21 ± 3.85	162.71 ± 5.16	243.08 ± 10.86	384.76 ± 8.35
	F	2.89 ± 0.04^{b}	8.06 ± 0.31	25.68 ± 0.65	99.1 ± 4.09	160.01 ± 3.18	247.5 ± 3.53	366.91 ± 6.41
	P-value	<0.01	0.82	0.08	0.19	0.67	0.71	0.12
BFP, %	M	6.68 ± 0.01^{a}	5.24 ± 0.01	5.70 ± 0.18	9.49 ± 0.33^{b}	10.47 ± 0.13^{b}	10.79 ± 0.24^{b}	11.98 ± 0.13^{b}
	F	6.19 ± 0.01^{b}	5.14 ± 0.13	5.60 ± 0.16	10.7 ± 0.38^{a}	11.28 ± 0.09^{a}	11.92 ± 0.07^{a}	12.93 ± 0.12^{a}
	P-value	<0.01	0.46	0.67	0.04	<0.01	<0.01	<0.01

[a-b] Means within a row with different superscripts significantly different ($P < 0.05$).
[1] BPC: body protein content; BPP: body protein proportion; BFC: body fat content; BFP: body fat proportion.
[2] M = male group (n = 6 sampled birds), F = female group (n = 6 sampled birds).

Table 6. Gender difference in body composition retention of broilers in thermoneutral groups.

Items[1]	Sex[2]	Stage, d					
		1–7	8–14	15–21	22–28	29–35	35–42
BPR, g/Kg	M	147.67 ± 1.49^{b}	174.43 ± 2.72^{b}	203.12 ± 0.41^{b}	166.60 ± 4.66	252.37 ± 10.23	262.08 ± 8.43^{a}
	F	159.03 ± 3.63^{a}	183.84 ± 2.55^{a}	227.30 ± 5.82^{a}	146.09 ± 7.87	255.89 ± 19.63	239.40 ± 6.47^{b}
	P-value	0.02	0.03	<0.01	0.05	0.88	0.06
BPE, %	M	50.55 ± 0.60	69.51 ± 0.66	69.26 ± 1.65	68.68 ± 1.34^{a}	70.04 ± 1.65^{a}	79.91 ± 1.35^{a}
	F	51.75 ± 0.49	69.50 ± 0.71	70.99 ± 0.92	60.38 ± 0.82^{b}	60.16 ± 1.07^{b}	67.12 ± 1.10^{b}
	P-value	0.15	0.99	0.38	<0.01	<0.01	<0.01
BFR, g/Kg	M	35.73 ± 0.36^{b}	52.88 ± 0.82	126.92 ± 0.25^{b}	90.61 ± 2.54	128.67 ± 5.22^{b}	192.73 ± 6.20
	F	38.84 ± 0.89^{a}	51.47 ± 0.71	175.33 ± 4.49^{a}	83.46 ± 4.49	175.61 ± 13.47^{a}	190.18 ± 5.14
	P-value	<0.01	0.23	<0.01	0.20	<0.01	0.76
BFE, %	M	26.17 ± 0.31	43.00 ± 0.41^{a}	88.31 ± 2.11^{b}	65.72 ± 1.28^{a}	60.43 ± 1.42^{b}	91.16 ± 1.54^{a}
	F	27.03 ± 0.26	39.70 ± 0.40^{b}	111.74 ± 1.45^{a}	60.69 ± 0.82^{b}	69.82 ± 1.24^{a}	82.71 ± 1.36^{b}
	P-value	0.06	<0.01	<0.01	<0.01	<0.01	<0.01

$^{a\text{-}b}$Means within a row with different superscripts significantly different ($P < 0.05$).

[1] BPR: body protein retention rate; BPE: body protein deposition efficiency; BFR: body fat retention rate; BFE: body fat deposition efficiency.

[2] M = male group (n = 6 sampled birds), F = female group (n = 6 sampled birds).

Table 7. Gender difference in body composition of broilers in heat stress groups (1–28 d with thermoneutral temperature, 29–42 d with high temperature).

Items[1]	Sex[2]	Age, d						
		1	7	14	21	28	35	42
BPR, g	M	9.27 ± 0.31	31.57 ± 0.93	95.90 ± 1.17	188.29 ± 3.09	319.20 ± 5.67^{a}	454.96 ± 7.70^{a}	575.34 ± 9.16^{a}
	F	9.55 ± 0.22	31.84 ± 0.38	92.10 ± 1.4	181.24 ± 0.95	285.96 ± 3.34^{b}	412.24 ± 4.44^{b}	513.27 ± 11.29^{b}
	P-value	0.48	0.79	0.06	0.08	<0.01	<0.01	<0.01
BPC, %	M	19.62 ± 0.07	18.78 ± 0.04	19.94 ± 0.13^{b}	20.42 ± 0.07	21.23 ± 0.16	20.99 ± 0.07	19.72 ± 0.11^{b}
	F	19.71 ± 0.25	19.43 ± 0.18	20.50 ± 0.11^{a}	20.13 ± 0.18	20.70 ± 0.07	20.80 ± 0.17	20.37 ± 0.07^{a}
	P-value	0.73	0.10	<0.01	0.15	0.13	0.32	0.02
BFR, g	M	3.14 ± 0.10^{a}	8.76 ± 0.28	27.45 ± 0.47	88.69 ± 3.17	159.93 ± 3.9	253.30 ± 5.07	378.41 ± 7.49^{a}
	F	2.86 ± 0.08^{b}	8.20 ± 0.21	25.37 ± 0.59	97.98 ± 3.2	159.60 ± 3.3	248.88 ± 1.83	345.75 ± 6.18^{b}
	P-value	0.04	0.14	0.05	0.07	0.95	0.43	<0.01
BFC, %	M	6.65 ± 0.00^{a}	5.17 ± 0.07	5.71 ± 0.14	9.63 ± 0.39^{b}	10.64 ± 0.16^{b}	11.69 ± 0.16^{b}	12.97 ± 0.14^{b}
	F	5.91 ± 0.02^{b}	5.01 ± 0.16	5.65 ± 0.11	10.91 ± 0.26^{a}	11.37 ± 0.22^{a}	12.56 ± 0.09^{a}	13.74 ± 0.29^{a}
	P-value	<0.01	0.35	0.72	0.02	0.02	<0.01	0.04

$^{a\text{-}b}$Means within a row with different superscripts significantly different ($P < 0.05$).

[1] BPR: body protein retention rate; BPE: body protein deposition efficiency; BFR: body fat retention rate; BFE: body fat deposition efficiency.

[2] M = male group (n = 6 sampled birds), F = female group (n = 6 sampled birds).

to 42 d under thermoneutral conditions, and during 22 to 28 d and 35 to 42 d in heat stress. There was a clear discrepancy during stages 1 to 7 d, 15 to 21 d, and 29 to 35 d in the BFR between males and females, with the females exhibiting a significantly higher value, but there were no significant differences between genders during stage 29 to 35 d under heat stress. Males exhibit higher BFE than females during stages 8 to 14 d, 22 to 28 d, and 35 to 42 d, whereas females are higher than males during stages 15 to 21 d and 29 to 35 d.

Table 8. Gender difference in body composition retention of broilers in heat stress groups (1–28 d with thermoneutral temperature, 29 –42 d with high temperature).

Items[1]	Sex[2]	Stage, d					
		1–7	8–14	15–21	22–28	29–35	36–42
BPR, g/Kg	M	158.74 ± 3.41^{b}	175.21 ± 0.45^{b}	195.17 ± 2.31^{b}	156.25 ± 5.29	287.67 ± 17.40	248.61 ± 16.74
	F	168.13 ± 1.60^{a}	179.54 ± 1.15^{a}	211.29 ± 2.84^{a}	146.14 ± 2.07	301.01 ± 9.84	250.05 ± 12.64
	P-value	0.04	0.04	0.02	0.11	0.52	0.95
BPE, %	M	55.65 ± 0.65	67.48 ± 0.49	64.59 ± 0.80	66.21 ± 0.58^{a}	67.77 ± 1.49	59.79 ± 1.81^{a}
	F	57.05 ± 1.09	66.96 ± 0.62	64.51 ± 0.78	58.34 ± 0.74^{b}	71.13 ± 1.10	54.09 ± 0.82^{b}
	P-value	0.30	0.53	0.94	<0.01	0.10	<0.01
BFR, g/Kg	M	37.92 ± 0.39	51.8 ± 0.47	134.12 ± 2.56^{b}	85.02 ± 2.88	197.84 ± 11.97	258.38 ± 17.40
	F	40.88 ± 0.29	50.96 ± 0.36	169.45 ± 3.19^{a}	85.38 ± 1.20	212.81 ± 6.96	239.73 ± 12.11
	P-value	0.03	0.19	<0.01	0.09	0.31	0.40
BFE, %	M	30.01 ± 0.35	40.01 ± 0.29	87.38 ± 1.09^{b}	63.39 ± 0.56^{a}	78.97 ± 1.74^{b}	96.39 ± 2.92^{a}
	F	29.19 ± 0.56	38.93 ± 0.36	108.14 ± 1.32^{a}	59.97 ± 0.76^{b}	85.20 ± 1.33^{a}	80.43 ± 1.22^{b}
	P-value	0.24	0.04	<0.01	<0.01	0.02	<0.01

$^{a\text{-}b}$Means within a row with different superscripts significantly different ($P < 0.05$).

[1] BPR: body protein retention rate; BPE: body protein deposition efficiency; BFR: body fat retention rate; BFE: body fat deposition efficiency.

[2] M = male group (n = 6 sampled birds), F = female group (n = 6 sampled birds).

Table 9. Interaction effect of gender and temperature on the body composition retention of 35 d and 42 d broilers.

Items[1]	Age, d	Treatment[2]				P-value[3]		
		TM	TF	HM	HF	Sex	Temperature	Interaction
BPC, g	35	485.40 ± 11.70	422.72 ± 3.29	454.96 ± 7.70	412.24 ± 4.44	<0.01	<0.01	0.20
	42	678.06 ± 10.51	573.02 ± 9.12	575.34 ± 9.16	513.27 ± 11.29	<0.01	<0.01	0.06
BPP, %	35	21.59 ± 0.11	20.37 ± 0.07	20.99 ± 0.07	20.80 ± 0.17	<0.01	0.44	<0.01
	42	21.13 ± 0.06	20.19 ± 0.09	19.72 ± 0.11	20.37 ± 0.07	0.11	<0.01	<0.01
BPR, g/Kg	28−35	252.37 ± 10.23	255.89 ± 19.63	287.67 ± 17.4	301.01 ± 9.84	0.58	0.01	0.75
	36−42	262.08 ± 8.43	239.40 ± 6.47	248.61 ± 16.74	250.05 ± 12.64	0.38	0.91	0.32
	28−42	256.92 ± 7.25	244.58 ± 6.86	267.17 ± 16.13	275.71 ± 11.13	0.86	0.08	0.35
BPE, %	28−35	70.04 ± 1.65	60.16 ± 1.07	67.77 ± 1.49	71.13 ± 1.10	0.03	<0.01	<0.01
	36−42	79.91 ± 1.35	67.12 ± 1.1	59.79 ± 1.81	54.09 ± 0.82	<0.01	<0.01	0.01
	28−42	75.13 ± 1.41	66.73 ± 1.06	63.74 ± 1.54	62.38 ± 0.89	<0.01	<0.01	<0.01
BFC g	35	243.08 ± 10.86	247.5 ± 3.53	253.30 ± 5.07	248.88 ± 1.83	1.00	0.37	0.49
	42	384.76 ± 8.35	366.91 ± 6.41	378.41 ± 7.49	345.75 ± 6.18	<0.01	0.07	0.31
BFP, %	35	10.79 ± 0.24	11.92 ± 0.07	11.69 ± 0.16	12.56 ± 0.09	<0.01	<0.01	0.39
	42	11.98 ± 0.13	12.93 ± 0.12	12.97 ± 0.14	13.74 ± 0.29	<0.01	<0.01	0.65
BFR, g/Kg	28−35	128.67 ± 5.22	175.61 ± 13.47	197.84 ± 11.97	212.81 ± 6.96	<0.01	<0.01	0.13
	36−42	192.73 ± 6.20	190.18 ± 5.14	258.38 ± 17.40	239.73 ± 12.11	0.36	<0.01	0.49
	28−42	162.85 ± 4.60	182.16 ± 5.11	227.90 ± 13.76	225.78 ± 9.12	0.35	<0.01	0.25
BFE, %	28−35	60.43 ± 1.42	69.82 ± 1.24	78.97 ± 1.74	85.2 ± 1.33	<0.01	<0.01	0.29
	36−42	91.16 ± 1.54	82.71 ± 1.36	96.39 ± 2.92	80.43 ± 1.22	<0.01	0.44	0.06
	28−42	76.96 ± 1.43	76.71 ± 1.27	88.04 ± 2.15	82.63 ± 1.19	0.09	<0.01	0.11

[1] BPC: body protein content; BPP: body protein proportion; BPR: body protein retention rate; BPE: body protein deposition efficiency; BFC: body fat content; BFP: body fat proportion; BFR: body fat retention rate; BFE: body fat deposition efficiency.

[2] TM: thermoneutral male group (n = 6 sampled birds); TF: thermoneutral female group (n = 6 sampled birds); HM: heat stress male group (thermoneutral in 1−28 d, heat stress in 29−42 d) (n = 6 sampled birds); HF: heat stress female group (thermoneutral in 1−28 d, heat stress in 29−42 d) (n = 6 sampled birds).

[3] $P < 0.05$ meant that there was a significant difference between different groups.

The interaction effect of temperature and gender on body composition at 35 d and 42 d were shown in Table 9. In general, there were significant differences in BPC, BPE, BFC, BFP, and BFE between the genders of broilers, and significant differences in BPC, BPP, BPE, BFP, BFR, and BFE between 2 temperatures. The interaction between genders and temperatures was observed in BPP and BPE.

Body Protein and Body Fat Deposition Curve

The estimated values for the parameters of the Gompertz equations are shown in Table 10, and the R^2 for the models ranged from 0.9935 to 0.9988. According to the model curves shown in Figure 1 and Figure 2, the efficiency of retention showed an initial increase followed by a subsequent fall, displaying an overall S-shaped curve. The following equations for body protein and body fat deposition in the thermoneutral groups were obtained:

$$\text{Body protein weight of male broilers}: \mathrm{BPW(t)} = 1843.6\mathrm{e}^{-5.1366\mathrm{e}^{-0.0388\mathrm{t}}}$$

$$\text{Body protein weight of female broilers}: \mathrm{BPW(t)} = 1293.8\mathrm{e}^{-4.7438\mathrm{e}^{-0.0417\mathrm{t}}}$$

$$\text{Body fat weight of male broilers}: \mathrm{BFW(t)} = 1702.7\mathrm{e}^{-6.1452\mathrm{e}^{-0.0336\mathrm{t}}}$$

Table 10. Parameters of body protein and body fat deposition curves.

Items	Sex[1]	Parameters						
		$\beta 0$[2]	$\beta 1$	$\beta 2$	AIP[3]	WIP[4]	MWG[5]	R^2
Thermoneutral								
Body protein	M	1843.6	5.1366	0.0388	42.18	678.22	26.32	0.9979
	F	1293.8	4.7438	0.0417	37.33	475.96	19.85	0.9988
Body fat	M	1702.7	6.1452	0.0336	54.04	626.39	21.05	0.9935
	F	1031.4	5.9759	0.0416	42.97	379.43	15.78	0.9965
Heat stress								
Body protein	M	992.1	4.9603	0.0527	30.39	364.97	19.23	0.9986
	F	881.2	4.7077	0.0517	29.97	324.18	16.76	0.9984
Body fat	M	1183.2	6.2350	0.0403	45.41	435.27	17.54	0.9972
	F	700.3	6.1667	0.0514	35.39	257.63	13.24	0.9974

[1] M: male group (n = 6 sampled birds); F: female group (n = 6 sampled birds).

[2] $\beta 0$: asymptote, body component weight at adult age, g.

[3] AIP: age at the inflection point, the age at which the growth rate is maximum, calculated as AIP $= (\text{In}\beta 1) / \beta 2$, d.

[4] WIP: body weight at the inflection point, the body weight at which the growth rate is maximum, calculated by WIP $= \beta 0 / \mathrm{e}$, g.

[5] MWG: the maximum growth rate, calculated by MWG $= \beta 2 \times$ WIP, g/d.

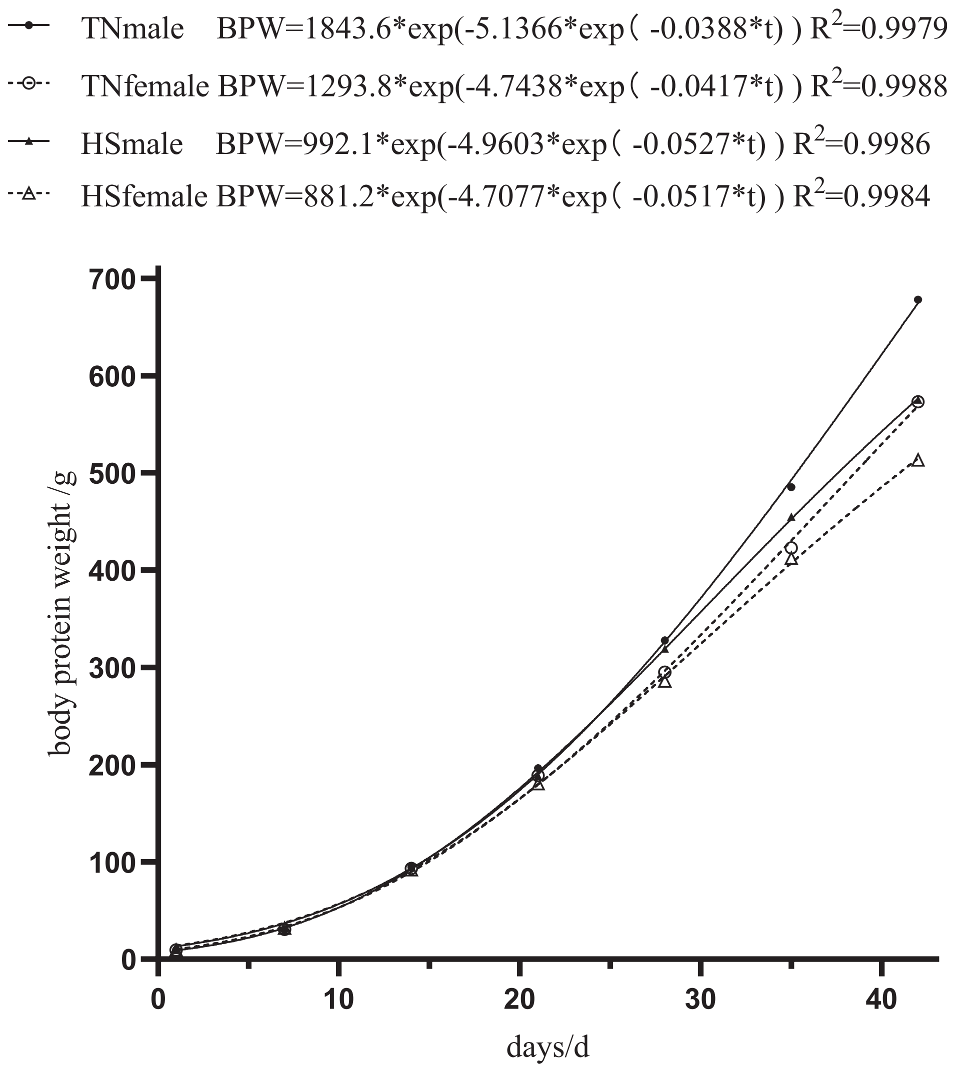

Figure 1. Protein deposition curves of broilers.

$$\text{Body fat weight of female broilers}: \mathrm{BFW(t)} = 1031.4e^{-5.9759e^{-0.0416t}}.$$

Where t means age (d).

The following equations for body protein and body fat deposition in the heat stress groups were obtained:

$$\text{Body protein weight of male broilers}: \mathrm{BPW(t)} = 992.1e^{-4.9603e^{-0.0527t}}$$

$$\text{Body protein weight of female broilers}: \mathrm{BPW(t)} = 881.2e^{-4.7077e^{-0.0517t}}$$

$$\text{Body fat weight of male broilers}: \mathrm{BFW(t)} = 1183.2e^{-6.2350e^{-0.0403t}}$$

$$\text{Body fat weight of female broilers}: \mathrm{BFW(t)} = 700.3e^{-6.1667e^{-0.0514t}}.$$

Where t means age (d).

Body Amino Acid Composition

The results of amino acid composition content in the carcass and feather as presented in Table 11 to Table 13. Overall, it is indicated that there were no significant differences in amino acid content between genders at the same life stage, as observed in both the carcass and feathers. Similarly, there were no significant differences in amino acid content between different ambient temperatures in both the carcass and feather.

Based on our statistical analysis, it can be concluded that significant differences were observed among different ages, primarily concentrated in the 0 to 14 d period. There was no significant difference in the amino acid composition of the feather after 21 d.

Amino Acid Pattern

The amino acid pattern can be defined as the percentage of a single amino acid to lysine. According to the above processing, the amino acid pattern of carcass and feather can be divided into 2 stages among which 0 to 14 d and 15 to 42 d. The amino acid content and pattern are shown in Table 14.

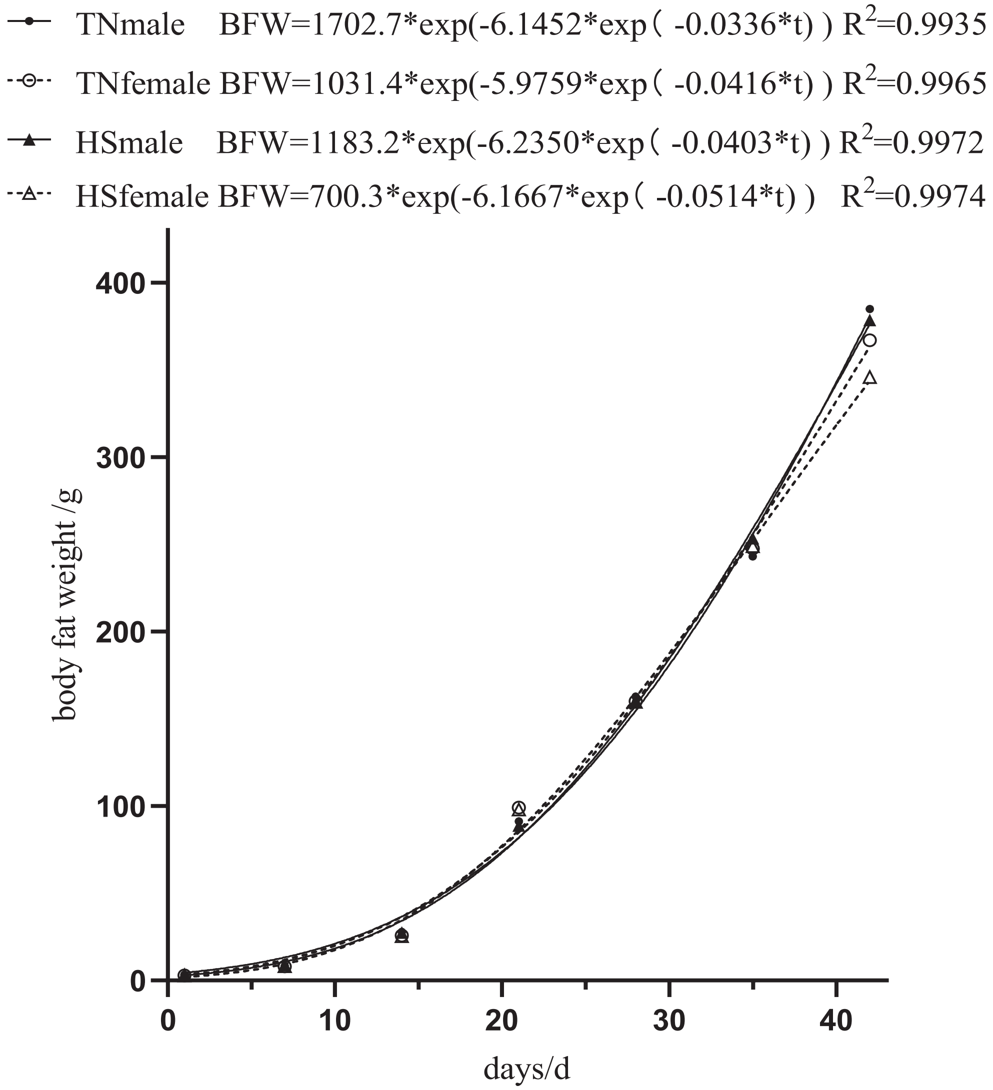

Figure 2. Fat deposition curves of broilers.

DISCUSSION

The results of this study revealed significant differences in body protein, body fat deposition, and amino acid content among broilers based on gender and temperature conditions. Moreover, an important finding was the significant interaction between gender and temperature in BPP and BPE which influenced differently depending on the combination of gender and temperature. This highlights the complex nature of the impact of environmental conditions on the nutrition and growth of broilers. The establishment of the body protein, fat deposition curves, and amino acid pattern of broilers provides valuable insight into the nutritional requirements and growth patterns of commercial broilers.

Arbor Acres Broiler Performance Objectives (Aviagen, 2022) reported that the BW of male broilers reached 3.20 Kg and the BW of females reached 2.76 Kg under good management and environmental conditions along with recommended nutrient levels. Compared to the Brazilian standard (Rostagno et al., 2011), which sets the BW of broilers after 42 d at 3.04 Kg for males and 2.48 Kg for females, the BW of broilers in our study is superior. The practical BW of broilers in the current study is higher than the NRC (National Research, 1994), which specifies a BW of 2.09 Kg for males and 1.74 Kg for female broilers.

Based on the aforementioned criteria, it is evident that the production performance of broilers varies among different genders. Male broilers outperformed females as indicated by higher BW and CW starting from 14 d in our study. This effect has been established in many previous studies (Brewer et al., 2012; Zuidhof et al., 2014). The body protein and fat retention in males were better than in females during the later period. Besides, the BPC was higher in males than in females, but the trend was the opposite for BFC from 21 to 42 d. A previous study showed that sire strains are a better choice than dam strains for selection against fatness in broilers (Leenstra and Pit, 1988).

The adverse effects of high temperatures on broiler production (Al-Abdullatif and Azzam, 2023) and body composition (Maharjan et al., 2021) are well described. Yalçin et al. (1997) found that the BW of broilers reared at high temperatures was 23% lower than that of their

Table 11. Amino acid content of broiler carcass in thermoneutral group.[1]

AA	Age, d						
	1	7	14	21	28	35	42
Male							
Cys	0.91 ± 0.01^{a}	0.83 ± 0.01^{ab}	0.79 ± 0.03^{ab}	0.74 ± 0.16^{ab}	0.72 ± 0.16^{ab}	0.80 ± 0.08^{ab}	0.69 ± 0.01^{b}
Met	2.70 ± 0.02^{a}	2.41 ± 0.20^{b}	2.41 ± 0.22^{b}	2.40 ± 0.21^{b}	2.39 ± 0.37^{b}	2.50 ± 0.03^{b}	2.38 ± 0.07^{b}
Asn	8.11 ± 0.02^{a}	7.32 ± 0.85^{a}	7.44 ± 0.81^{a}	8.28 ± 0.95^{a}	8.22 ± 0.92^{a}	8.46 ± 0.17^{a}	8.01 ± 0.13^{a}
Thr	4.02 ± 0.02^{a}	3.91 ± 0.44^{a}	3.97 ± 0.39^{a}	3.83 ± 0.49^{b}	3.82 ± 0.49^{b}	3.80 ± 0.57^{b}	3.83 ± 0.08^{b}
Ser	4.20 ± 0.02^{a}	3.84 ± 0.20^{ab}	3.86 ± 0.49^{ab}	3.86 ± 0.38^{ab}	3.93 ± 0.54^{ab}	3.26 ± 0.42^{b}	3.41 ± 0.05^{b}
Gln	13.28 ± 0.03^{a}	13.07 ± 1.38^{a}	13.18 ± 1.40^{a}	13.73 ± 1.61^{a}	13.62 ± 1.60^{a}	14.60 ± 0.29^{a}	13.37 ± 0.23^{a}
Gly	7.23 ± 0.04^{a}	6.38 ± 0.72^{b}	6.41 ± 0.77^{b}	6.81 ± 0.83^{ab}	6.76 ± 0.82^{ab}	6.93 ± 0.19^{a}	6.40 ± 0.95^{b}
Ala	6.16 ± 0.01^{ab}	6.41 ± 0.62^{a}	6.55 ± 0.62^{a}	6.26 ± 0.71^{ab}	6.61 ± 0.71^{a}	6.17 ± 0.12^{ab}	5.85 ± 0.07^{b}
Val	5.22 ± 0.07^{a}	5.21 ± 0.35^{a}	4.59 ± 0.46^{b}	4.64 ± 0.34^{b}	4.75 ± 0.34^{b}	4.69 ± 0.08^{b}	4.49 ± 0.08^{b}
Ile	4.50 ± 0.08^{a}	3.97 ± 0.29^{b}	4.11 ± 0.42^{b}	4.13 ± 0.27^{b}	4.18 ± 0.27^{b}	4.31 ± 0.03^{b}	4.17 ± 0.06^{b}
Leu	7.20 ± 0.04^{a}	7.07 ± 0.67^{ab}	6.86 ± 0.69^{b}	6.76 ± 0.71^{b}	6.71 ± 0.71^{b}	6.73 ± 0.09^{b}	6.71 ± 0.13^{b}
Tyr	2.17 ± 0.01^{a}	1.93 ± 0.22^{ab}	2.01 ± 0.12^{ab}	2.05 ± 0.23^{ab}	2.21 ± 0.23^{a}	1.78 ± 0.04^{b}	1.78 ± 0.06^{b}
Phe	4.02 ± 0.02^{a}	3.85 ± 0.40^{a}	3.80 ± 0.36^{a}	3.89 ± 0.41^{a}	3.86 ± 0.41^{a}	3.70 ± 0.05^{a}	3.53 ± 0.07^{a}
Lys	6.05 ± 0.01^{a}	6.67 ± 0.64^{a}	6.37 ± 0.66^{a}	6.96 ± 0.68^{a}	6.91 ± 0.66^{a}	6.80 ± 0.10^{a}	6.89 ± 0.10^{a}
His	2.00 ± 0.03^{b}	2.21 ± 0.24^{ab}	2.49 ± 0.23^{a}	2.54 ± 0.29^{a}	2.52 ± 0.28^{a}	2.49 ± 0.26^{a}	2.47 ± 0.37^{a}
Arg	6.91 ± 0.01^{a}	6.97 ± 0.58^{a}	6.96 ± 0.59^{a}	6.93 ± 0.73^{a}	7.23 ± 0.73^{a}	7.24 ± 0.01^{a}	7.23 ± 0.07^{a}
Pro	4.47 ± 0.01^{a}	4.15 ± 0.44^{b}	4.13 ± 0.43^{b}	4.52 ± 0.52^{a}	4.69 ± 0.52^{a}	4.63 ± 0.09^{a}	4.49 ± 0.05^{a}
Female							
Cys	0.91 ± 0.01^{a}	0.84 ± 0.02^{a}	0.76 ± 0.01^{a}	0.76 ± 0.12^{a}	0.79 ± 0.12^{a}	0.73 ± 0.04^{a}	0.71 ± 0.01^{a}
Met	2.68 ± 0.01^{a}	2.41 ± 0.01^{b}	2.40 ± 0.03^{b}	2.39 ± 0.31^{b}	2.36 ± 0.32^{b}	2.50 ± 0.05^{b}	2.40 ± 0.05^{b}
Asn	8.22 ± 0.05^{a}	8.15 ± 0.02^{a}	8.40 ± 0.15^{a}	8.88 ± 1.30^{a}	9.15 ± 1.35^{a}	8.14 ± 0.10^{a}	8.28 ± 0.30^{a}
Thr	3.95 ± 0.06^{a}	3.90 ± 0.05^{a}	3.99 ± 0.10^{a}	3.81 ± 0.62^{b}	3.80 ± 0.64^{a}	3.82 ± 0.06^{b}	3.85 ± 0.24^{b}
Ser	4.04 ± 0.14^{a}	3.84 ± 0.15^{ab}	3.89 ± 0.15^{ab}	3.89 ± 0.66^{ab}	4.02 ± 0.68^{a}	3.20 ± 0.97^{b}	3.41 ± 0.35^{b}
Gln	13.52 ± 0.09^{a}	13.29 ± 0.05^{a}	13.74 ± 0.28^{a}	13.98 ± 2.23^{a}	14.49 ± 2.31^{a}	14.41 ± 0.30^{a}	13.15 ± 0.24^{a}
Gly	7.30 ± 0.13^{a}	7.08 ± 0.14^{a}	7.23 ± 0.17^{a}	7.09 ± 1.18^{a}	7.33 ± 1.22^{a}	6.48 ± 0.14^{b}	6.19 ± 0.18^{b}
Ala	6.23 ± 0.04^{ab}	6.04 ± 0.04^{b}	6.28 ± 0.12^{ab}	6.55 ± 1.03^{a}	6.78 ± 1.07^{a}	6.07 ± 0.11^{b}	5.87 ± 0.12^{b}
Val	5.15 ± 0.06^{a}	5.23 ± 0.13^{a}	4.66 ± 0.18^{b}	4.63 ± 0.54^{b}	4.78 ± 0.56^{b}	4.61 ± 0.16^{b}	4.53 ± 0.03^{b}
Ile	4.54 ± 0.09^{a}	3.98 ± 0.15^{b}	4.21 ± 0.04^{b}	4.16 ± 0.46^{b}	4.30 ± 0.47^{b}	4.21 ± 0.13^{b}	4.21 ± 0.05^{b}
Leu	7.28 ± 0.05^{a}	7.09 ± 0.08^{ab}	6.87 ± 0.07^{b}	6.86 ± 1.00^{b}	6.72 ± 1.00^{b}	6.74 ± 0.17^{b}	6.75 ± 0.14^{b}
Tyr	2.14 ± 0.03^{a}	2.07 ± 0.04^{ab}	2.03 ± 0.07^{ab}	2.19 ± 0.36^{a}	2.27 ± 0.37^{a}	1.73 ± 0.47^{b}	1.80 ± 0.10^{b}
Phe	4.09 ± 0.03^{a}	3.87 ± 0.04^{a}	3.85 ± 0.02^{a}	3.83 ± 0.54^{a}	3.96 ± 0.56^{a}	3.74 ± 0.09^{b}	3.59 ± 0.07^{b}
Lys	6.06 ± 0.05^{a}	6.71 ± 0.11^{a}	6.47 ± 0.08^{a}	6.95 ± 0.85^{a}	6.94 ± 0.88^{a}	6.79 ± 0.29^{a}	6.95 ± 0.35^{a}
His	2.04 ± 0.15^{b}	$2.29 \pm 0.13a^{b}$	2.50 ± 0.17^{a}	2.59 ± 0.33^{a}	2.50 ± 0.35^{a}	2.42 ± 0.07^{a}	2.46 ± 0.06^{a}
Arg	6.90 ± 0.05^{a}	6.94 ± 0.03^{a}	6.96 ± 0.11^{a}	6.97 ± 0.80^{a}	5.93 ± 0.83^{a}	7.21 ± 0.15^{a}	7.20 ± 0.61^{a}
Pro	4.47 ± 0.05^{a}	4.10 ± 0.04^{b}	4.13 ± 0.11^{b}	4.54 ± 0.71^{a}	4.69 ± 0.73^{a}	4.63 ± 0.09^{a}	4.51 ± 0.14^{a}

[a-b] Means within a row with different superscripts significantly different ($P < 0.05$).

[1] The data is as a percentage of total protein retention (% of protein) (n = 6 sampled birds).

counterparts reared at optimal temperatures. In the present study, the BW of chickens in the thermoneutral male group was 3,213.90 g, while the BW of chickens in the heat stress male group was 2,818.67 g. This decrease of about 13% may be attributed to the breed and the degree of heat stress.

Heat stress also decreased BPC, BPP, and BPE. However, overall, there was no significant effect on the BPR. In a previous study, heat-exposed chickens showed a significant decrease in BPC, protein gain, and protein retained: protein intake ratio (Geraert et al., 1996). Heat stress increased the content of body fat at 35 d and 42 d and increased the overall BFR and BFE as well. Lu et al. (2007) demonstrated an exacerbation of abdominal fat deposition under high-temperature conditions; the increased accumulation of abdominal fat in broilers under high-temperature conditions is likely an adaptive response. This phenomenon can be attributed to the conversion of dietary energy into fat stores, resulting in decreased heat production and subsequently reducing the need for heat dissipation.

Many nonlinear mathematical models are available for describing broiler growth and body composition, with some authors (Macleod, 1999; Sakomura et al., 2005; Sakomura et al., 2015) suggesting that the Gompertz curve provides the most accurate representation. The equations established in this study consistently yielded R^2 values higher than 0.99, indicating a high degree of fit. According to Duarte (1975), mature weight symbolizes genetic development potential and the effect of genes on growth, making this asymptotic measure a parameter arising from earlier growth phases. Caldas et al. (2019) established the Gompertz curves for protein and fat of Cobb broilers, with mature deposition amounts of 1,001 g and 526 g, and the maximum growth rates were found to be 4.9 g/d and 5.1 g/d, with the inflection point at 34.5 d and 35.1 d, respectively. Our findings revealed a higher proportion of mature body components, a faster growth rate at inflection point, and a delayed age of inflection point emergence than the study by Caldas. The delayed age of inflection signifies an increase in the accumulation of body components, which could be attributed to the rapid progress in the genetics or the genetic variation between different strains.

According to experimental data from Marcato et al. (2008), both Ross and Cobb male broilers exhibited higher levels of maximum body component deposition compared to females. However, the maximum rate of inflection was lower in males than in females, and the

Table 12. Amino acid content of broiler feather in thermoneutral groups.[1]

AA	Age, d						
	1	7	14	21	28	35	42
Male							
Cys	5.82 ± 0.01^{b}	4.58 ± 0.07^{c}	4.45 ± 0.03^{c}	5.38 ± 0.06^{b}	5.69 ± 0.06^{b}	6.05 ± 0.03^{ab}	6.83 ± 0.07^{a}
Met	0.47 ± 0.05^{b}	0.77 ± 0.06^{a}	0.78 ± 0.0^{a}	0.53 ± 0.03^{b}	0.53 ± 0.03^{b}	0.41 ± 0.02^{c}	0.51 ± 0.02^{b}
Asn	6.49 ± 0.04^{a}	6.03 ± 0.04^{a}	5.82 ± 0.06^{a}	6.10 ± 0.12^{a}	6.29 ± 0.02^{a}	6.29 ± 0.03^{a}	6.43 ± 0.02^{a}
Thr	3.95 ± 0.06^{b}	3.54 ± 0.03^{b}	3.64 ± 0.01^{b}	4.31 ± 0.04^{a}	4.47 ± 0.01^{a}	4.46 ± 0.03^{a}	4.52 ± 0.02^{a}
Ser	10.19 ± 0.0^{a}	8.50 ± 0.06^{b}	8.61 ± 0.01^{b}	9.66 ± 0.03^{a}	10.26 ± 0.0^{a}	10.58 ± 0.01^{a}	10.67 ± 0.0^{a}
Gln	9.28 ± 0.01^{b}	9.22 ± 0.03^{b}	9.44 ± 0.02^{b}	10.8 ± 0.04^{a}	10.8 ± 0.10^{a}	10.5 ± 0.14^{a}	10.8 ± 0.06^{a}
Gly	7.14 ± 0.0^{a}	6.88 ± 0.1^{a}	6.28 ± 0.02^{b}	6.35 ± 0.03^{b}	6.82 ± 0.05^{a}	7.08 ± 0.03^{a}	7.11 ± 0.04^{a}
Ala	3.09 ± 0.03^{b}	3.06 ± 0.03^{b}	3.18 ± 0.02^{b}	3.75 ± 0.04^{a}	4.13 ± 0.03^{a}	4.33 ± 0.02^{a}	4.41 ± 0.01^{a}
Val	5.96 ± 0.10^{a}	5.27 ± 0.03^{a}	4.20 ± 0.0^{b}	5.88 ± 0.08^{a}	6.23 ± 0.20^{a}	7.07 ± 0.10^{a}	7.34 ± 0.20^{a}
Ile	4.39 ± 0.03^{a}	4.02 ± 0.0^{a}	3.26 ± 0.0^{b}	4.18 ± 0.10^{a}	4.39 ± 0.13^{a}	4.66 ± 0.15^{a}	4.84 ± 0.07^{a}
Leu	6.99 ± 0.0^{a}	6.35 ± 0.0^{a}	5.83 ± 0.0^{b}	6.96 ± 0.05^{a}	7.54 ± 0.10^{a}	7.98 ± 0.13^{a}	8.05 ± 0.03^{a}
Tyr	2.29 ± 0.0^{a}	2.10 ± 0.0^{a}	1.79 ± 0.0^{b}	1.87 ± 0.05^{a}	1.91 ± 0.10^{a}	1.37 ± 0.20^{b}	1.60 ± 0.13^{b}
Phe	4.90 ± 0.10^{a}	4.21 ± 0.20^{a}	3.79 ± 0.0^{a}	4.14 ± 0.05^{a}	4.39 ± 0.03^{a}	4.60 ± 0.06^{a}	4.73 ± 0.07^{a}
Lys	1.50 ± 0.10^{b}	2.16 ± 0.1^{a}	2.37 ± 0.23^{a}	2.28 ± 0.22^{a}	2.36 ± 0.32^{a}	1.97 ± 0.05^{a}	1.90 ± 0.06^{a}
His	1.57 ± 0.1^{a}	1.46 ± 0.11^{a}	1.11 ± 0.2^{a}	0.84 ± 0.10^{a}	0.79 ± 0.03^{a}	0.64 ± 0.04^{a}	0.67 ± 0.03^{a}
Arg	6.91 ± 0.04^{a}	6.03 ± 0.05^{a}	5.19 ± 0.0^{a}	5.71 ± 0.07^{a}	6.04 ± 0.04^{a}	6.19 ± 0.05^{a}	6.57 ± 0.06^{a}
Pro	8.57 ± 0.0^{a}	6.96 ± 0.06 ^{b}	6.68 ± 0.0^{b}	7.54 ± 0.03^{b}	8.20 ± 0.05^{a}	8.86 ± 0.10^{a}	9.42 ± 0.12^{a}
Female							
Cys	5.80 ± 0.02^{b}	4.67 ± 0.06^{c}	4.55 ± 0.02^{c}	5.28 ± 0.03^{b}	5.69 ± 0.06^{b}	6.08 ± 0.06^{ab}	5.80 ± 0.02 ^{b}
Met	0.41 ± 0.00^{b}	0.70 ± 0.02^{a}	0.79 ± 0.00^{a}	0.58 ± 0.030^{b}	0.53 ± 0.02^{b}	0.46 ± 0.06^{c}	0.41 ± 0.00^{b}
Asn	6.40 ± 0.03^{a}	6.08 ± 0.05^{a}	5.88 ± 0.08^{a}	6.13 ± 0.10^{a}	6.27 ± 0.02^{a}	6.30 ± 0.04^{a}	6.40 ± 0.03^{a}
Thr	3.92 ± 0.05^{b}	3.50 ± 0.01^{b}	3.60 ± 0.03^{b}	4.34 ± 0.02^{a}	4.40 ± 0.05^{a}	4.40 ± 0.02^{a}	3.92 ± 0.05^{b}
Ser	10.20 ± 0.00^{a}	8.53 ± 0.02^{b}	8.68 ± 0.03^{b}	9.60 ± 0.02^{a}	10.23 ± 0.0^{a}	10.50 ± 0.03^{a}	10.20 ± 0.00^{a}
Gln	9.25 ± 0.00^{b}	9.23 ± 0.03^{b}	9.40 ± 0.04^{b}	10.8 ± 0.05^{a}	10.8 ± 0.10^{a}	10.6 ± 0.18^{a}	9.25 ± 0.00^{b}
Gly	7.15 ± 0.00^{a}	6.80 ± 0.10^{a}	6.23 ± 0.05^{b}	6.30 ± 0.02^{b}	6.75 ± 0.03^{a}	7.03 ± 0.05^{a}	7.15 ± 0.00^{a}
Ala	3.10 ± 0.02^{b}	3.08 ± 0.02^{b}	3.15 ± 0.05^{b}	3.70 ± 0.04^{a}	4.11 ± 0.04^{a}	4.30 ± 0.03^{a}	3.10 ± 0.02^{b}
Val	5.93 ± 0.12^{a}	5.25 ± 0.04^{a}	4.23 ± 0.03^{b}	5.86 ± 0.06^{a}	6.20 ± 0.15^{a}	7.10 ± 0.12^{a}	5.93 ± 0.12^{a}
Ile	4.37 ± 0.04^{a}	4.00 ± 0.05^{a}	3.22 ± 0.10^{b}	4.14 ± 0.15^{a}	4.35 ± 0.16^{a}	4.69 ± 0.12^{a}	4.37 ± 0.04^{a}
Leu	6.94 ± 0.02^{a}	6.30 ± 0.03^{a}	5.81 ± 0.09^{b}	6.90 ± 0.06^{a}	7.64 ± 0.10^{a}	7.88 ± 0.15^{a}	6.94 ± 0.02^{a}
Tyr	2.32 ± 0.03^{a}	2.15 ± 0.03^{a}	1.74 ± 0.05^{b}	1.89 ± 0.09^{a}	1.90 ± 0.15^{a}	1.47 ± 0.10^{b}	2.32 ± 0.03^{a}
Phe	4.95 ± 0.14^{a}	4.23 ± 0.22^{a}	3.76 ± 0.00^{a}	4.10 ± 0.07^{a}	4.30 ± 0.06^{a}	4.50 ± 0.05^{a}	4.95 ± 0.14^{a}
Lys	1.48 ± 0.10^{b}	2.15 ± 0.16^{a}	2.30 ± 0.27^{a}	2.25 ± 0.12^{a}	2.30 ± 0.32^{a}	1.95 ± 0.03^{a}	1.48 ± 0.10^{b}
His	1.59 ± 0.10^{a}	1.45 ± 0.11^{a}	1.10 ± 0.22^{a}	0.80 ± 0.10^{a}	0.75 ± 0.03^{a}	0.60 ± 0.03^{a}	1.59 ± 0.10^{a}
Arg	6.95 ± 0.04^{a}	6.00 ± 0.03^{a}	5.15 ± 0.06^{a}	5.70 ± 0.08^{a}	6.08 ± 0.03^{a}	6.15 ± 0.03^{a}	6.95 ± 0.04 ^{a}
Pro	8.50 ± 0.00^{a}	6.99 ± 0.06 ^{b}	6.67 ± 0.05^{b}	7.52 ± 0.04^{b}	8.25 ± 0.07^{a}	8.80 ± 0.13^{a}	8.50 ± 0.00^{a}

[a-b]Means within a row with different superscripts significantly different ($P < 0.05$).

[1]The data is as a percentage of total protein retention (% of protein) (n = 6 sampled birds).

inflection point age was delayed in males as well. In our study, male broilers exhibited higher mature protein deposition compared to females, with a delay in the inflection point age by 5 d, which suggested a greater potential for lean tissue growth in male broilers. Furthermore, Sakomura (Sakomura et al., 2005) reported that the maximum fat deposition rates in males are higher than in females, consistent with the findings of the present study but contradicting the results of Marcato et al. (2008). This inconsistency may be attributed to variation in the age at slaughter. Gous et al. (1999) observed a significant increase in the fat deposition rate in females after reaching 56 d of age. They suggested that this additional fat deposition serves as preparation for future egg laying. These phenomena implied that growth rates vary among breeds and genders, indicating the differences in nutritional demands and rearing practices regarding the analyzed strains.

Additionally, in the present study, the equation parameters for broilers in the thermoneutral group were higher than those for broilers in the heat stress group, regardless of gender. The same conclusion was drawn in the study conducted by Hruby et al. (1996), with a maximal protein response of 1,085 g at 21.1°C, 958 g at 26.7°C, and 819 g at 32.2°C, and the age at the inflection point was 7.3, 7.4, and 6.7 wk, respectively. High ambient temperature adversely affects the growth of broilers and decreases the mature body weight. To achieve precision feeding, it is necessary to regulate nutrient intake using appropriate growth curves under different environmental conditions.

Previous experiments have shown differences in the amino acid composition between feathers and carcasses of broilers (Fisher et al., 1981). Thus, the amino acid patterns of feather and carcass were separately determined in this study. Apart from alanine, no significant difference was found in amino acid content between male and female broilers at the same age. These findings indicate that gender has no affect on amino acid pattern, which is consistent with a previous study (Tian et al., 2007). The present study revealed that temperature did not alter the amino acid pattern in broilers.

In the current study, there were differences in the amino acid pattern of the carcass at different ages, primarily between 1 d and other days of age, which was primarily because the yolk sac of broilers was not fully digested at the early growth stage. The yolk sac accounts for a large proportion of body weight and

Table 13. Amino acid content of body carcass and feather of broilers in heat stress groups.[1]

AA	Age, d							
	35	42	35	42	35	42	35	42
	Male carcass		Female carcass		Male feathers		Female feathers	
Cys	0.85 ± 0.03^{a}	0.70 ± 0.03^{a}	0.78 ± 0.17^{a}	0.73 ± 0.18^{a}	6.08 ± 0.06^{a}	6.80 ± 0.08^{a}	6.05 ± 0.03^{a}	6.83 ± 0.07^{a}
Met	2.40 ± 0.22^{a}	2.41 ± 0.22^{a}	2.49 ± 0.20^{a}	2.38 ± 0.36^{a}	0.43 ± 0.03^{a}	0.50 ± 0.02^{b}	0.48 ± 0.02^{a}	0.49 ± 0.02^{b}
Asn	8.32 ± 0.85^{a}	8.04 ± 0.81^{a}	8.20 ± 0.98^{a}	8.25 ± 0.82^{a}	6.24 ± 0.02^{a}	6.40 ± 0.03^{a}	6.25 ± 0.08^{a}	6.40 ± 0.09^{a}
Thr	3.81 ± 0.46^{a}	3.87 ± 0.39^{a}	3.85 ± 0.44^{a}	3.83 ± 0.45^{b}	4.43 ± 0.06^{a}	4.42 ± 0.05^{a}	4.40 ± 0.03^{a}	4.55 ± 0.04^{a}
Ser	3.25 ± 0.20^{a}	3.36 ± 0.48^{a}	3.26 ± 0.34^{a}	3.53 ± 0.50^{a}	10.50 ± 0.02^{a}	10.63 ± 0.04^{a}	10.54 ± 0.08^{a}	10.60 ± 0.04^{a}
Gln	14.07 ± 1.39^{a}	13.28 ± 1.40^{a}	14.33 ± 1.50^{a}	13.32 ± 1.65^{a}	10.59 ± 0.13^{a}	10.83 ± 0.09^{a}	10.54 ± 0.15^{a}	10.86 ± 0.03^{a}
Gly	6.88 ± 0.73^{a}	6.41 ± 0.76^{a}	6.38 ± 0.86^{a}	6.16 ± 0.72^{a}	7.09 ± 0.06^{a}	7.11 ± 0.07^{a}	7.13 ± 0.11^{a}	7.18 ± 0.14^{a}
Ala	6.21 ± 0.61^{a}	5.75 ± 0.68^{a}	6.16 ± 0.74^{a}	5.91 ± 0.61^{a}	4.30 ± 0.09^{a}	4.31 ± 0.04^{a}	4.33 ± 0.09	4.31 ± 0.111^{a}
Val	4.71 ± 0.30^{a}	4.59 ± 0.33^{a}	4.64 ± 0.38^{a}	4.55 ± 0.44^{a}	7.17 ± 0.14^{a}	7.24 ± 0.10^{a}	7.09 ± 0.15^{a}	7.28 ± 0.16^{a}
Ile	4.27 ± 0.21^{a}	4.11 ± 0.44^{a}	4.33 ± 0.29^{a}	4.18 ± 0.37^{a}	4.60 ± 0.13^{a}	4.80 ± 0.10^{a}	4.76 ± 0.14^{a}	4.84 ± 0.08^{a}
Leu	6.97 ± 0.66^{a}	6.86 ± 0.60^{a}	6.75 ± 0.72^{a}	6.73 ± 0.81^{a}	7.90 ± 0.13^{a}	8.02 ± 0.09^{a}	7.88 ± 0.10^{a}	8.06 ± 0.06^{a}
Tyr	1.83 ± 0.23^{a}	1.79 ± 0.15^{a}	1.85 ± 0.23^{a}	1.77 ± 0.33^{a}	1.39 ± 0.23^{a}	1.67 ± 0.18^{b}	1.47 ± 0.25^{a}	1.60 ± 0.12^{a}
Phe	3.85 ± 0.41^{a}	3.60 ± 0.38^{a}	3.79 ± 0.46^{a}	3.56 ± 0.42^{a}	4.55 ± 0.06^{a}	4.70 ± 0.03^{a}	4.66 ± 0.08^{a}	4.70 ± 0.09^{a}
Lys	6.77 ± 0.68^{a}	6.87 ± 0.66^{a}	6.90 ± 0.67^{a}	6.90 ± 0.67^{a}	1.95 ± 0.03^{a}	1.99 ± 0.09^{a}	1.93 ± 0.08^{a}	1.99 ± 0.03^{a}
His	2.46 ± 0.24^{a}	2.49 ± 0.25^{a}	2.44 ± 0.28^{a}	2.51 ± 0.28^{a}	0.68 ± 0.09	0.69 ± 0.04^{a}	0.63 ± 0.08^{a}	0.69 ± 0.04^{a}
Arg	7.33 ± 0.59^{a}	7.28 ± 0.57^{a}	6.99 ± 0.71^{a}	7.20 ± 0.63^{a}	6.19 ± 0.07^{a}	6.47 ± 0.04^{a}	6.29 ± 0.02^{a}	6.47 ± 0.07^{a}
Pro	4.65 ± 0.43^{a}	4.43 ± 0.44^{a}	4.62 ± 0.51^{a}	4.60 ± 0.51^{a}	8.80 ± 0.14^{a}	9.41 ± 0.15^{a}	8.82 ± 0.13^{a}	9.32 ± 0.11^{a}

[a-b] Means within a row with different superscripts significantly different ($P < 0.05$).

[1] The data is as a percentage of total protein retention (% of protein) (n = 6 sampled birds).

inevitably affects the amino acid composition of the carcass. There were significant differences in the composition of amino acids of the carcass, such as valine, leucine, and isoleucine, between 14 d and other ages, demonstrating a distinct difference pattern between the 0 and 14 d period and the 15 to 42 d period.

Studies have shown that the amino acid composition of feather proteins varies under normal temperature

Table 14. Amino acid pattern of broilers at different ages.

AA	Age, d			
	0–14		15–42	
	AA content[1]	The ratio to lysine	AA content[1]	The ratio to lysine
Carcass				
Cys	0.87	14	0.74	11
Met	2.56	40	2.75	40
Asn	7.95	125	8.43	122
Thr	3.95	62	3.82	55
Ser	3.98	62	3.62	53
Gln	13.29	209	13.92	202
Gly	7.00	110	6.75	98
Ala	6.21	97	6.27	91
Val	5.20	82	4.64	67
Ile	4.25	67	4.21	61
Leu	7.16	112	6.75	98
Tyr	2.08	33	1.98	29
Phe	3.96	62	3.76	55
Lys	6.37	100	6.90	100
His	2.14	34	2.50	36
Arg	6.95	109	7.25	105
Pro	4.30	67	4.59	66
Feather				
Cys	4.95	2.46	5.99	2.81
Met	0.67	0.34	0.49	0.23
Asn	6.11	3.04	6.28	2.95
Thr	3.71	1.84	4.44	2.09
Ser	9.10	4.53	10.29	4.84
Gln	9.31	4.63	10.77	5.06
Gly	6.77	3.37	6.84	3.21
Ala	3.11	1.55	4.15	1.95
Val	5.14	2.56	6.63	3.11
Ile	3.89	1.93	4.52	2.12
Leu	6.39	3.18	7.63	3.59
Tyr	2.06	1.02	1.69	0.79
Phe	4.30	2.14	4.46	2.10
Lys	2.01	1.00	2.13	1.00
His	1.38	0.68	0.74	0.35
Arg	6.04	3.01	6.13	2.88
Pro	7.40	3.68	8.51	4.00

[1] The data is as a percentage of total protein retention (% of protein) (n = 6 sampled birds).

(Graham et al., 1949; McCasland and Richardson, 1966; Tian, 2005), most likely because of variances in species and methods of measurement. In the current study, the differences in feather composition among different ages are primarily concentrated within the 0 to 14 d period. Therefore, the same stage division as for the carcass is adopted to determine the amino acid pattern in feathers.

In conclusion, the current study found that high temperature limited the deposition of body protein and body fat in broilers. Furthermore, gender and temperature had no effect on amino acid pattern. This study also obtained the body protein and body fat growth models of different gender under different ambient temperatures. The following equations of the thermoneutral groups were obtained:

$$\begin{aligned}\text{Body protein weight of male broilers} : \mathrm{BPW(t)} \\ = 1843.6\mathrm{e}^{-5.1366\mathrm{e}^{-0.0388\mathrm{t}}}\end{aligned}$$

$$\begin{aligned}\text{Body protein weight of female broilers} : \mathrm{BPW(t)} \\ = 1293.8\mathrm{e}^{-4.7438\mathrm{e}^{-0.0417\mathrm{t}}}\end{aligned}$$

$$\begin{aligned}\text{Body fat weight of male broilers} : \mathrm{BFW(t)} \\ = 1702.7\mathrm{e}^{-6.1452\mathrm{e}^{-0.0336\mathrm{t}}}\end{aligned}$$

$$\begin{aligned}\text{Body fat weight of female broilers} : \mathrm{BFW(t)} \\ = 1031.4\mathrm{e}^{-5.9759\mathrm{e}^{-0.0416\mathrm{t}}}.\end{aligned}$$

Where t means age (d).

The following equations of the heat stress groups were obtained:

$$\begin{aligned}\text{Body protein weight of male broilers} : \mathrm{BPW(t)} \\ = 992.1\mathrm{e}^{-4.9603\mathrm{e}^{-0.0527\mathrm{t}}}\end{aligned}$$

$$\begin{aligned}\text{Body protein weight of female broilers} : \mathrm{BPW(t)} \\ = 881.2\mathrm{e}^{-4.7077\mathrm{e}^{-0.0517\mathrm{t}}}\end{aligned}$$

$$\begin{aligned}\text{Body fat weight of male broilers} : \mathrm{BFW(t)} \\ = 1183.2\mathrm{e}^{-6.2350\mathrm{e}^{-0.0403\mathrm{t}}}\end{aligned}$$

$$\begin{aligned}\text{Body fat weight of female broilers} : \mathrm{BFW(t)} \\ = 700.3\mathrm{e}^{-6.1667\mathrm{e}^{-0.0514\mathrm{t}}}.\end{aligned}$$

Where t means age (d).

DISCLOSURES

The authors declare that there have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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